Journal of the Royal Society of Western Australia, Vol. 62, Parts 1-4, 1979, p. 45-51.

Aspects of Science in Western Australia 1829-1979.
A volume to commemorate the 150th Anniversary of the founding of Western Australia.

The Western Rock Lobster, *Panulirus cygnus*

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Abstract

The supervision of the rock lobster industry and the management controls that have been introduced have been constantly reviewed so that Western Australia's multi-million dollar industry stands today as one of the few fisheries that can be said to be properly managed. The management strategy has been determined by co-operative decisions between State and Commonwealth fisheries institutions and it has been based on reliable catch and effort data collected since the post-1945 expansion of the fishery, a broad understanding of the species biology after much research work by many scientists, and the application of modern fisheries models to assess levels of fishing effort and the possible effect on the stocks.

Introduction

The western rock lobster forms the basis of a multi-million dollar industry which began as an incidental fishery in the early 1900s when pots were pulled by hand from sail-powered fishing boats and the rock lobsters were mostly sold direct to the housewife by the fishermen.

Little management of the fishery was needed in those times even though, as early as 1897, a regulation was introduced to prohibit the sale of any rock lobster less than the legal size; the regulation, announced in March 1897 set a minimum legal weight of 8 oz. whieh was altered in September of the same year to 12 oz.

The control and management of the fishery has been the responsibility of the State Department of Fisheries and Wildlife and the Departments' management policy has always been based on the best research information available. Early research on the fundamental biology of this species was commenced in the 1940s by the CSIRO Fisheries Division through the efforts of the late Dr. K. Sheard (Sheard 1962). Due to the expansion of the State Fisheries Department's research and management unit and the recent major effort on larvae by CSIRO Fisheries and Oceanography Division, 6 scientists are currently engaged in research on the western rock lobster. At the conclusion of this present review a full list of the publications relating to research on the western rock lobster is presented.

The species (*Panulirus cygnus* George 1962) is endemic to Western Australia, occurring along the continental shelf of the west coast from North West Cape (21° 45′S) to Cape Leeuwin (34° 22′S). Fishermen expanded their operations from the two early centres at Fremantle and Geraldton and they now set their pots over an extensive area from the shallow coastal reefs to the edge of the shelf at 200 m. The present flourishing fishing centres are scattered along the west coast shelf at Kalbarri, Abrolhos Islands, Geraldton, Dongara, Cliff Head, Jurien Bay, Leeman, Cervantes, Lancelin, Fremantle and Bunbury. The annual production is approximately 8 000 tonnes, 95% of which is exported to the U.S.A. market as frozen uncooked tails.

In the mid 1960s, a serious concern was expressed by the scientists and the fishermen because the catches resulting from the rapid expansion of boats, men and pots in the previous 5 years or so had not resulted in a proportionate return to the fishermen. Thanks to the foresight of early fisheries administrators, records of catch and fishing effort had been gathered and as a result of intensified research on these records and a better understanding of the biology of the rock lobster, rigorous limitations were able to be placed on the total fishing effort to halt the decline in catch per unit effort. This was successfully achieved by limiting the number of pots permitted by each boat and restricting the total number of boats in the industry.

Annual production was maintained at a reasonable level but more recent research has shown that effort was again increasing due to an increase in the number of pot lifts over the season since fishermen were working more efficiently and more frequently than they had in the past. So in 1978 the length of the season was reduced by 6 weeks to assist fishermen to maintain a viable economic return.

Constant research into the best management techniques has proved that a natural fishery resource *is* capable of adequate management and the Western Australian rock lobster industry stands today as one of the very few fisheries in the world that can be regarded as well managed.

Because of this research and the results produced by the Western Australian scientists studying the western rock lobster, Perth was chosen in 1977 as the venue for a week-long Australian-American "Workshop on lobster and rock lobster ecology and physiology", the proceedings of which have been recently published (Phillips and Cobb 1977).

General biology and environment

In addition to the commercially important western rock lobster, there are 6 other species of rock lobster in Western Australia only one of which is commercially important. This is the southern rock lobster, *Jasus novaehollandiae* that is fished in south-east Australia. In Western Australia however, its density is not sufficient to support more than small catches at Esperance and Albany. Along the northern coast, 5 species of very wide ranging tropical rock lobsters (*Panulirus* spp.) are found in moderate concentrations in shallow reef and coral outcrops. These species have separate environmental preferences, are restricted in depth to the shallow reefs and do not support continuing catches (George 1968, 1974).

The western rock lobster occupies a subtropic (intermediate) geographical position between these southern and northern zones and occupies much of the relatively wide continental shelf that extends seaward from the west coast. The continental shelf has been subjected to significant sea level changes in the past and the former coastal fringing limestone reef flats now form lengthy submarine "ledges" that provide shelter for the rock lobster. It is a gregarious species and dense groups of several hundred can be found packed closely together in the undercut ledges of these submarine features.

The south-west swell that strikes the west coast is a major physical factor that results in both the constant wave action on the shallow reefs and the deep surges that are a fairly consistent feature of the submarine ledges. The seaweed kelps provide mobile cover around and over the entrances to the undercut ledges. The fauna and flora associated with seagrass beds and reef flats (molluscs, worms, coralline algae, seagrass itself and small crustacea) provide most of the food supply for the rock lobsters. (Joll, pers. comm.). Their feeding forays are usually restricted to hours of darkness; bright moonlight nights drastically reduce the catch in pots and most fishermen reduce their fishing effort during these periods. Predators on the rock lobsters include octopus (Joll 1977) as well as large predatory fish including sharks.

The western rock lobster is regarded as a "slow grower". Chittleborough (1974d) maintained and grew juveniles in the laboratory, indicating a growth-to-maturity period of about 6 years and achieved successful mating and egg carriage under these conditions. Growth occurs only after a moult when the old hard exoskeleton is shed and a new soft one is expanded to its new size by absorption of salt water. Food requirements and the general physiology of the rock lobster alter dramatically before, during and after each moult (Dall 1974a, b, 1975a, b, c, 1977; Dall and Barclay 1977) and they remain deep in their shelters until the new shell hardens in about 7 days.

At the time of adolescence, most if not all, individuals go through a distinct phase known as the "white" phase. The characteristic red-brown colour of the species is not present in the newly moulted shell which is parchment to light pink in colour; red pigment is gradually added to the shell until, after about 3 weeks, they are indistinguishable from the normal coloration. The white phase occurs regularly in November-December of each year in the shallower waters and a rapid offshore migration occurs during the "white" fishing season (George 1958b).

The sexes are separate in *P. cygnus* and sex ratios in the adult stock approximate 1:1 but because of differences in availability this ratio may vary significantly in pot catches (Morgan and Barker 1974). The size at first maturity of females and the mean size of breeding females varies significantly throughout the range of *P. cygnus* with the size at first maturity ranging from around 80 mm carapace length in the northern areas of the fishery to around 95 mm in southern areas (Morgan and Barker 1974). No information is available on the size of first maturity of males although it is probably similar to that of females in the same area.

Mating takes place in July-August and the female carries the black sperm packet (known locally as a "tar-spot") until November-December when the eggs are extruded and attach themselves to the pleopods. Fecundity varies linearly with the size of the rock lobster, a 100 mm carapace length female carrying 460 000 eggs (Morgan 1972). The eggs are carried on the pleopods for up to 6 weeks, depending on the water temperature, before hatching into the first phyllosoma larvae that peak during December and January.

Larvae and juveniles

Studies of the rock lobster larvae have been directed mainly towards understanding their movements in space and time and their ecology. Complementary investigations have also been made to measure the numbers of larvae that return to the coast at the end of the planktonic phase of the life cycle.

The newly hatched larvae or phyllosoma, rise up from the bottom, concentrate at the surface and become part of the plankton. The body of the phyllosoma is flat and leaflike with long legs and protuberent eyes. As there is no pigment or calcium in the skeleton, the body is colourless and transparent. The phyllosoma larvae swim actively toward a weak light source (Ritz 1972b) by beating their "feathery" legs and most movements are directed to rising in the water column since cessation of beating results in a slow descent. The phyllosoma larvae undergo a daily vertical migration in the upper part of the water column, rising towards the surface of the water toward dusk and then descending to lower depths as dawn approaches (Ritz 1972a). In their early stages they are transported offshore into the Indian Ocean by the effects of wind-driven surface transport acting on the larvae while they are at the surface at night (Chittleborough and Thomas 1969).

The larvae remain in the phyllosoma stages for 9 to 11 months during which time at least 9 phyllosoma stages are recognisable although the number of actual moults is considerably higher than this (George and Cawthorn 1962, Chittleborough and Thomas 1969, Braine *et al.* in press). The first phyllosoma stage is less than 2 mm in length and because they are almost transparent, are only just visible to the human eye; by the last phyllosoma stage, they are about 35 mm long.

The full extent of the larval distribution is not known but significant numbers of larvae have been caught during the intensive CSIRO Fisheries larval research programme as far offshore as 1 500 km (Phillips *et al.* in press). Less is known about the actual return paths of the larvae to the coast of Western Australia. Although many larvae are lost during the long period in the plankton, the survivors are eventually transported back to the edge of the continental shelf of Western Australia by the ocean circulation (Phillips 1977), the greater number arriving between August and December each year.

From this point the larval cycle is completed by the transparent puerulus stage which is similar in shape to the adult. The puerulus stage metamorphoses from the last phyllosoma stage just on or just beyond the continental shelf and then actively swims across the shelf and settles in the shallow reef areas along the coast (Phillips *et al.* 1978). Collecting devices made of artificial seaweed (Phillips 1972) have been designed specially to catch the settling puerulus and by their use, the times and relative densities of settlement from year to year have been able to be compared (Chittleborough and Phillips 1975, 1977). Settlement follows a lunar periodicity with catches being largely confined to the new moon period (Phillips 1975).

The settling puerulus moults into a small pigmented rock lobster about 3 cm long, similar to the adult. These juvenile rock lobsters remain in the shallow coastal reefs (depths of 1-20 m) for 3 to 6 years before migrating out into deeper areas on the continental shelf (Chittleborough 1974d).

Population biology

Much of the research effort which has been expended on the western rock lobster has been on those aspects of its population biology which are of direct importance in making decisions which affect the management of the fishery. Apart from the routine collection of catch and fishing-effort data for use in surplus-yield models these data have included (a) estimates of growth and mortality rates for use in various dynamic pool models of the fishery, (b) information on reproductive dynamics for assessing the likely impact of fishing on the reproductive potential of the stock and (c) various other biological data which have been used to answer more specific regional problems.

The "whites"

P. cygnus is unique among the world's commercially fished rock lobster stocks in that a significant part of the commercial fishery is based on pale coloured, newly moulted migratory animals locally known as "whites". Studies by George (1958b) established that these "whites" are all immature animals and move offshore from the shallow water reefs (where they have spent their early juvenile life) to deeper waters. This late November migration may take the animals on a journey of 25 km or more to an area which presumably is better suited than the inshore areas for the later release of the planktonic larvae. Since the "whites" are newly moulted animals their food requirements are high (Chittleborough 1975) and consequently their catchability by baited pots is likewise high (Morgan 1974b). This results in high catch rates being aehieved by the commercial fishermen in late November and December and it is during this 6 week period that about one third of the annual catch is taken.

Growth

Since, like all other crustacea, *P. cygnus* grows by moulting, the growth process may be considered to be a combination of two factors—the moult increment (the size increase at each moult) and the intermoult period (the time between moults). Field-tagging studies invariably are difficult to interpret in this light since the observed growth between release and recapture will consist of the unmeasured contributions from these two growth processes. Studies in aquaria however have been more fruitful and have enabled meaningful interpretation of field-growth studies.

The intermoult period increases with size in *P. cygnus* and for animals held in aquaria at 25°C the intermoult period is about 100 days for an animal of 76 mm carapace length (Chittleborough 1974d). Chittleborough (1976a) and Morgan (1977a) have shown that moult increment increases with age until the second year of post-larval life, then remains constant during the third year and then decreases with increasing age. The combination of these two processes results in a grown-in-length curve which approximates the von Bertalanffy (1938) curve and this curve has been used in the biological models of the fishery (Morgan 1977a).

Although the "average" growth curve has been used in biological models, growth rates in the natural population exhibit large variations as a result of the influences of limited food resources, high densities of rock lobsters (Chittleborough 1976b) and temperature variations (Morgan 1977a). In addition, animals held in aquaria were shown to exhibit a smaller moult increment with a mild deficiency of oxygen while frequency of moulting was reduced when animals were held in isolation (Chittleborough 1975).

Mortality

Mortality rates in *P. cygnus* may be considered in two parts, those produced by fishing operations (the fishing mortality rate, F) and those produced by natural causes such as predation (the natural mortality rate, M). Since, like all other crustaceans, *P. cygnus* cannot be individually aged, the usual methods of fisheries population dynamics of comparing the abundance of age classes to calculate F and M cannot be used and so alternative methods have been necessary. These have included direct estimation of M from tagging studies (Chittleborough 1970, Morgan 1974a) and the use of length/frequency data to estimate F and M (Morgan 1977a). These methods have indicated an annual value of M of about 0.2 (equivalent to 18% mortality each year) and a value of F of about 1.0 (equivalent to 63% mortality each year) for recent years. Thus, mortality due to fishing comprises some 80% of the total mortality suffered by legal-size rock lobsters.

Management of the fishery

Since the start of the commercial fishery in 1944/45, both the catch and the amount of fishing effort expended to take that catch have increased dramatically (Table 1). This has resulted in an inevitable decline in the catch per unit of effort. During the 1940s and 1950s management of the fishery was by means of a legal minimum length only, since the amount of fishing effort was relatively small and the catch per unit of effort was high enough for those engaged in the industry to achieve a satisfactory return from their fishing activities. In 1961, the Western Fisheries Research Committee met under the chairmanship of the then Director of Fisheries to co-ordinate the research efforts of State and Commonwealth programmes to assist in management not only of rock lobsters but of all the State's fishery resources.

As fishing effort further increased and catch per unit of effort further decreased it became apparent from the analyses of the available catch and effort data that more stringent management measures would be necessary to achieve the dual aims of providing a near maximum total catch and of providing a reasonable return (in terms of catch per unit of effort) to the individual operators in the fishery. The most direct way in which this could be achieved was by a limitation of effort policy and it was this strategy which was adopted by the State Government in 1962. The methods used to limit fishing effort at that time were a restriction on the number of vessels entitled to fish for rock lobsters and a limit on the number of pots each vessel was entitled to use. This pot allocation was based on boat length and was fixed at 3 pots per foot of boat length with a maximum of 200 pots per boat.

Later, a boat replacement policy was introduced which restricted a replacement vessel to the same size as that vessel which was being replaced. This measure prevented the number of pots used being increased by the building of a larger vessel. The effect of this legislation was to reduce fishing effort from about 10^7 pot lifts in 1962/63 to about 7 x 10^6 pot lifts in 1963/64. Total catch decreased somewhat from 9.3 x 10^6 kg in 1962/63 to 8.1 x 10^6 kg in 1963/64 but subsequently recovered to about 8.7 x 10^6 kg by 1966/67. Catch per pot lift improved slightly from an average of 1.04 kg per pot lift for the 3 years prior to the introduction of the legislation to 1.09 for the 3 subsequent years. However, the most important effect was that the rapid escalation of the fishing effort of the late 1950s was halted.

Since the introduction of this limited entry policy to control fishing effort, total catches have remained stable at about 8 x 10^6 kg although because of increased efficiency of the individual operators in the industry, fishing effort had by 1974 again increased to levels similar to those immediately prior to 1962. Further reduction in fishing effort was indicated since subsequent analysis of fisheries data and application of fisheries models confirmed the concern experessed in 1962 regarding the effect on catches of high levels of fishing effort. In addition concern was expressed about the effect of this high level of effort on the reproductive potential of the stock.

The limited entry nature of the fishery, however, has posed some problems in the selection of the most suitable methods to be used to achieve further fishing effort reduction. One of these problems is the increased capitalisation

Table 1

Average catch and fishing effort for the Western Australian rock lobster fishery, 1944–1975

Year	Average catch (kg x 10^6)	Average No. pot lifts (x 10^6)	Catch per pot lift	Average No. of men employed
1944/45–1948/49....	0·994	0·618	1·608	109
1949/50–1953/54....	3·547	2·284	1·553	402
1954/55–1958/59....	5·805	4·172	1·391	734
1959/60–1963/64....	8·541	7·815	1·093	1 378
1964/65–1968/69....	8·434	7·647	1·103	1 350
1969/70–1973/74....	7·338	9·407	0·780	1 668

of the industry brought about by the fact that the fishing licence (i.e. the right to fish) has acquired a considerable monetary value. This makes the reduction of boat or pot numbers an almost prohibitively expensive exercise either for Government or industry. Alternative strategies which effect each individual equally are therefore necessary and some of the options which have been examined are changing the legal minimum size and implementing additional closed seasons. In fact a 6 week additional closure has been implemented on a trial basis for the 1977/78 season. The problems of effort reduction in a highly capitalised, limited entry fishery such as the rock lobster industry have not been fully resolved but solutions will need to be found if increasing efficiency continues to result in increasing fishing effort.

Although the Western Australian rock lobster fishery stands as one of the few examples of a well-managed fishery, those management techniques that have been chosen have themselves resulted in a new set of problems. Present research is addressing itself to the resolution of these new problems.

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